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S O M E C I T R U S P R O B L E M S.

ROOT FORMATION AND FERTILIZING.

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The results of a study of the root formation of citrus trees in Puerto Rico shows the feeding root area, in clay soils, to be much more limited than has been generally believed. This is of much importance considering that most of the existing groves are planted on clay soils. This paper was read at a citrus growers field meeting held March 31, 1931, and it is being published after consultation with the fruit growers who have cooperated in the work upon which it is based. Some of these growers have already profited by the findings here reported and it is hoped that many more will do so after becoming acquainted with existing conditions.

Differences in root development that may be ascribed to the part of the tree above the bud-union were not studied, neither were differences due to individuality of the stock upon which any tree was budded. The conclusions drawn from the study are based entirely upon the root development of the average, apparently normal, tree growing in light sandy soil, heavy clay soil and some of the intermediate soil types.

ROUGH LEMON STOCK. - The rough lemon is, at present, the predominating stock in most of the older groves in Puerto Rico, and therefore the data in connection with that are very complete. In well aerated sandy soil the horizontal spread of the roots was found to be much greater than the horizontal spread of the branches of the same tree. The depth was found to be variable, usually the largest number of the feeding roots were found in the upper eight inches of the soil, but frequently many were found at a depth of two feet and occasionally as far down as five to six feet or more. But in no case was a well developed tap-root encountered.

In heavy clay soil the horizontal spread of the roots was found to be practically equal to that of the branches. In few cases only were feeding roots found a few inches beyond the horizontal spread of the branches. The depth of the feeding roots was found to be surprisingly small. Some roots were encountered at a depth of about twelve inches but practically all the feeding roots were located in the upper eight inches of soil, and usually more were present in the upper two than in the lower two inches of the eight inch

stratum. A well developed tap root was not found on any of the trees examined.

In loose, well aerated clay soils or in sandy clay, that was not too compact, the extent of the root development was found to differ according to the compactness, the amount of vegetation and the frequency of plowing or cultivation. Soils that had not been plowed or cultivated for many years, and which were covered by a heavy sod, were usually found to be fairly permeable. In such soils some feeding roots were usually found at some distance beyond the horizontal spread of the branches, but never as many as in the soil under the branches.

SOUR ORANGE STOCK. - For the purpose of the present discussion it is sufficient to state that in clay soils the horizontal spread of the roots of the sour orange is as great as that of the rough lemon but the number of roots per square foot is usually much less. The depth of the anchor roots of sour orange is usually much greater than that of the rough lemon, but most of the feeding roots are located close to the surface, similar to those of the rough lemon. A well developed tap root was found on most of the trees examined. It may be mentioned that in the heavy clay soils many of the deeper roots seemed to be unusually much decayed. That is perhaps due to a lack of aeration at some prolonged period in the trees' existence.

GRAPEFRUIT STOCK. - The root development of grapefruit stock on clay soils seems to differ mainly from that of rough lemon stock in having some deep anchor roots. The feeding roots were found mainly in the upper eight inches of soil, spreading horizontally to a distance similar to those of the rough lemon stock in similar soils. A well developed tap root was usually found.

ROOT FORMATION ON HILLSIDES. - The purpose of tree roots is partly that of anchorage and special provisions are usually made for resisting strains caused by wind or gravity. This is always noticeable on hillsides where the root system of citrus trees is much more extensive on the upper than on the lower side of the slope. That is of importance in fertilizing and will be discussed later.

CONCLUSIONS. - The following conclusions may be drawn from the data at hand: (1) In more or less impermeable soil, in which sufficient aeration is lacking, the feeding roots do not extend much below the upper eight inches. The horizontal spread is seldom beyond that of the tips of the branches except where the soil is not plowed or cultivated, and where the surface is kept permeable by a heavy growth of annuals; (2) in well aerated soils the feeding roots may spread out an indefinite distance beyond the branches, even though the soil is cultivated periodically, for under those conditions the roots may thrive in the deeper strata; (3) it is evident that soil aeration is the underlying reason

for high planting, as practiced in Puerto Rico, and that any contemplated change in method of planting must be based upon soil aeration. (4) The present method of planting must involve mulching in order that it may be most successful. The soil in the mound upon which the tree is planted is much subject to drying especially during the first few years before the branches afford much shade. Inevitably that restricts root development, and it can be prevented, to some extent, by maintaining a heavy grass mulch.

AN EXPERIMENT IN PLANTING. - With the premises that depth of root formation is governed by soil aeration, and that soil aeration is governed mainly by physical condition and moisture content, the conclusion follows that by meeting those requirements a deep root system can be induced. That this conclusion is correct needs to be proved and the following experiment was started for that purpose: Holes 5 feet in diameter and 4 feet deep were dug in clay soil. At one side of each hole a small excavation was made and filled with rock. A tube 4-1/2 to 5 feet long was placed vertically upon that rock after which the hole was filled. Some holes were filled with clay mixed with varying amounts of decayed material from the San Juan dump heap. In other holes bamboo stakes were placed vertically a few inches apart and soil of varying composition was filled in. After the soil had settled, trees, budded on rough lemon, sour orange and grapefruit stocks were planted in the soil mounded up to a height of about 12 inches over each hole, and a heavy grass mulch was applied.

These trees will be liberally fertilized, and watered when the moisture content of the soil goes below what may be considered the minimum for normal tree growth. Once a week, or oftener when necessary, a rod will be let down into the tube, mentioned previously, when the water content of the hole is large enough to be pumped out the water will be removed by means of a hand pump inserted through the tube. After a few years growth the trees will be removed, a few at a time, for the purpose of studying root development. If the method is successful it can be used, advantageously, especially on hilly land where drainage can be provided by tubing connecting one hole with another and with the outlet at the bottom of the slope.

METHOD OF FERTILIZING AND PROBABLE LOSS OF FERTILIZERS. -

The fertilizer problem includes many phases, two of which have been studied by the writer during the past few months. One, where shall the fertilizer be applied and how shall it be covered? And the other, what is the probable loss after it is applied? The first question will be answered upon the basis of the study of the root system mentioned previously, and the second upon the basis of present knowledge of soil physics and chemistry applied to local conditions.

WHERE SHALL THE FERTILIZER BE APPLIED? - Three distinct methods of fertilizing have been practised in Puerto Rico in groves with trees ten years old, or older. (1) Spreading the fertilizers broadcast over the whole soil area except close to the trunk of the tree; (2) applying the fertilizer in a trench around the tree at the same distance from the trunk as the tips of the horizontal branches; (3) spreading the fertilizer on the soil area covering the outer part of a circle in which the tree trunk is the center and the tips of the horizontal branches the circumference.

With present knowledge of root development it is obvious that no one will use the first-mentioned method on clay soils. The trench method has apparently given good result in many cases and it seems reasonable to suppose that it may do so. Yet, it must be remembered that after cutting most of fine roots in the region, in which the trench is made, much loss of fertilizer salts may take place before new roots are formed.

The third method has the advantage over the two former that the fertilizers cannot fail to come in contact with an abundance of feeding roots; and if there is sufficient moisture in the soil the roots will be able to avail themselves of the fertilizers immediately.

The trench method offers no problem in regard to covering the fertilizer, but the last mentioned method does. The tree roots are so close to the surface that even very shallow hoeing destroys many of them. In one grove water is pumped from irrigation furrows and applied under each tree by means of a hose. That is an excellent method and not as costly as it may appear to be. One of the disadvantages of it is that it puddles the soil, more or less, and leaves it in a condition that is not very favorable to the tree roots.

The best method suggesting itself is that of mulching. A cover crop can be grown in most of the groves, for the trees seldom cover the ground entirely. If that were cut, from time to time, and spread over the roots, no hoeing would be needed. The old-time argument that mulch is undesirable because it draws the roots to the surface is valueless in this case for the roots are as close to the surface as they can get. A combination of mulching and a suitable system of sprinkle irrigation will be almost ideal. The mulch will prevent puddling of the soil when the water is applied and it prevents evaporation after it is applied.